**NERRS Science Collaborative Progress Report for the Period 03/01/12 through 08/31/12**

**Project Title:** Managing for resilience in the face of climate change: a scientific approach to targeted oyster restoration in San Francisco Bay and Elkhorn Slough, California

**Principal Investigator(s):** Matt Ferner
**Project start date:** 11/15/2011
**Report compiled by:** Matt Ferner and Kerstin Wasson
**Contributing team members and their role in the project:**

| | |
|---|---|
| Collaboration Lead: | Marilyn Latta, Project Manager<br>California State Coastal Conservancy<br>Oakland, CA<br>Role on project: Marilyn oversees integration of the applied science with the needs of core local and regional end-users. |
| Co-Principal Investigators: | Andy Chang, Research Scientist<br>San Francisco Bay National Estuarine Research Reserve<br>Tiburon, CA<br>Role on project: Andy co-leads laboratory experiments, environmental monitoring, oyster surveys and population connectivity studies with a focus on San Francisco Bay sites.<br><br>Ted Grosholz, Professor of Environmental Science and Policy<br>University of California, Davis / Bodega Marine Laboratory<br>Davis, CA<br>Role on project: Ted advises the science team, participates in environmental monitoring and oyster surveys in San Francisco Bay and Elkhorn Slough, and facilitate interactions with end-users.<br><br>Kerstin Wasson, Research Coordinator<br>Elkhorn Slough National Estuarine Research Reserve<br>Watsonville, CA<br>Role on project: Kerstin coordinates and leads development of end-user products resulting from the project. She also assists with field monitoring and overall project management.<br><br>Chela Zabin, Research Scientist<br>University of California, Davis<br>Davis, CA<br>Role on project: Chela co-leads environmental monitoring and oyster surveys with a focus on Elkhorn Slough sites. She also works closely with the Collaboration Lead and regional end-users. |
| Graduate Investigators: | Jill Bible, Graduate Student<br>University of California, Davis / Bodega Marine Laboratory<br>Bodega Bay, CA<br>Role on project: Jill co-leads laboratory tests of potential stressors on oysters collected from study sites that span a range of environmental conditions in San Francisco Bay. |

Brian Cheng, Graduate Student
University of California, Davis / Bodega Marine Laboratory
Bodega Bay, CA
Role on project: Brian co-leads laboratory tests of potential stressors on oysters collected from study sites that span a range of environmental conditions in San Francisco Bay.

Anna Deck, Research Technician
San Francisco Bay National Estuarine Research Reserve
Tiburon, CA
Role on project: Anna co-leads environmental monitoring, oyster surveys and population connectivity studies with a focus on San Francisco Bay sites. She also leads data management and assists with overall project coordination and communication.

**A. Progress overview**

Project Goal: The overall goal of this project is **to increase the resilience of oyster restoration projects in the face of climate change.** We will do this by developing restoration planning tools for end users that characterize and prioritize restoration sites and source material for restoration projects at two central California estuaries. We will also achieve this goal by synthesizing broader lessons learned about best approaches for enhancing resilience by shellfish in the face of climate change. These end-products will be based on science tailored to address critical information gaps identified by local and regional end-uers. We will quantify stressor levels across sites within and between the two estuaries, determine which climate-related and other anthropogenic stressors have the greatest potential to impact native oysters, investigate how these stressors interact, and characterize oyster population connectivity among the San Francisco Bay sites.

Accomplishments: We adhered to our project timeline and moved forward with both the applied science and collaborative components of our project during this reporting period. For the applied science component, we revised science plans following feedback from end-users and the full project team. We began monitoring oysters and environmental stressors in both estuaries and have now completed two quarters of extensive data collection with the help of a dedicated volunteer and several of our core end-users. We hired an undergraduate technician for the summer and began laboratory experiments on oyster responses to individual and multiple stressors. We also broadened our scientific collaboration to include Drs. Anne Todgham and Nate Miller who are collecting data on oyster physiology throughout our lab experiments this year. For the collaboration component, we summarized our response to early end-user feedback on project design, solicited additional end-user feedback on our final science plans, prepared for the upcoming West Coast Olympia Oyster Restoration Workshop, and submitted a proposal requesting funds to support transfer between NERRS Science Collaborative project teams in Oregon and California. We also designed and created our project website to provide a long-term forum for information exchange between scientists and end-users involved in oyster restoration planning in central California and more broadly across the range of the Olympia oyster. We continue to share ideas and updates with our entire project team through monthly conference calls, email discussions, and our recently reorganized Basecamp online workspace.

**B. Working with Intended Users**

Our collaborative objectives for this reporting period were to integrate end-user feedback into our applied science plans and to make those plans and other documents broadly available. We accomplished these objectives and made progress in other aspects of end-user collaboration, as described below.

*Summary of end-user feedback and resulting adaptation of project design*

At the end of the last reporting period, we had completed a synthesis of all the early end-user feedback received through an electronic survey and working group meeting. During this period, we adapted our project design in response to this feedback, and summarized these adaptations in an updated version of the synthesis of end-user feedback. This summary is now available on the project website, and has been sent to all survey respondents with a note expressing gratitude for their participation and indicating that their feedback had made a very real difference to project design.

*Additional end-user feedback on preliminary science plans*

On 3/19/2012, we distributed preliminary science plans to our core group of end-users and requested feedback on our objectives, approach and detailed methods. We received only a small amount of specific feedback and finalized detailed science plans accordingly. In the next six months we will refine our conceptual model of Olympia oyster ecology in central California, draft conceptual designs for the restoration planning tools we will create, and present those ideas to our end-users for criticism and guidance.

*Public website for project*

We developed online content and worked with a contractor to design and officially launch our new project website (http://oysters-and-climate.org/). In early September we will distribute a brief project update and the website link to all the end-users in our database.

*"Living" project description*

We consolidated several of our planning documents into a single project description that we augmented with recent accomplishments and will continue to update periodically to reflect our progress. This "living" project description is posted on our project website along with other critical documents.

*Planning for West Coast Olympia Oyster Restoration Workshop*

We communicated with this group of end-users about the status of our project and expressed our interest in attending the next workshop planned for October 2012. We submitted a project enhancement proposal to the NERRS Science Collaborative to support travel for our full project team to that workshop. Our intention is to also schedule an extended period of interaction with scientists and end-users from the Oregon Olympia oyster project funded by the NERRS Science Collaborative.

*Linkages to on-the-ground Olympia oyster restoration projects in both estuaries*

We actively engaged with on-going Olympia oyster restoration projects during this reporting period, ensuring that we were aware of the key issues and challenges being faced on the ground, so we can include these perspectives in the preparation of our final restoration planning tools, and so that we can continue to strengthen relationships with key players in local oyster restoration. Chela Zabin, Ted Grosholz and Marilyn Latta were heavily involved in one of the largest oyster restoration projects to date in San Francisco Bay. They worked together with one of our key end-users (Kathy Boyer, lead scientist on the project) and others to complete construction of a new "living shoreline" project just a few miles south of the San Francisco Bay NERR site of China Camp. In Elkhorn Slough, Chela Zabin and Kerstin Wasson helped to implement the largest oyster restoration project in this estuary to date, a project funded by California Department of Fish and Game's Environmental Enhancement Fund. Engagement of key staff from our NERRS Science Collaborative project with such field oyster restoration projects will enhance the relevance of project findings for practitioners.

## C. Progress on project objectives for this reporting period

Our progress on collaborative objectives of this project is described above. We also made substantial progress on our applied science objectives during this reporting period. Each objective is listed below and followed by a brief summary of our recent activities. All raw data are being archived on a secure data server hosted by San Francisco State University. Over the next six months we will make that server remotely accessible to the full project team and will populate the server with all documents and files associated with the project.

*Intensively monitor the magnitude and variability of environmental stressors on a spatial scale relevant to restoration projects.*

We began measuring the major physical and biological stressors that affect oyster populations at a variety of study sites with a particular emphasis on those stressors expected to be influenced by global climate change. As with site selection, our exact selection of stressors was influenced by early feedback from end-users and includes air and water temperature, pH, salinity, sedimentation, turbidity, chlorophyll *a* (food level), competitive (overgrowth) effects of invasive species, and at some sites dissolved oxygen. At multiple sites in both San Francisco Bay and Elkhorn Slough, we are characterizing environmental stressors through high frequency data collection using dataloggers and repeated sampling. Temperature is being measured using TidBit dataloggers (Onset Computer) placed at Mean Lower Low Water (MLLW). Sedimentation rates are being measured with sediment marker poles, sediment tubes, and grain size analysis. Due to the higher cost of salinity loggers (Onset Computer model U24), we placed a logger at MLLW at only one representative site per region in each estuary (three per estuary). Other water quality parameters are being measured by repeated sampling with handheld instruments and discrete water samples. We also plan to supplement data from existing NERR monitoring programs in the two estuaries by installing a YSI 6600 data sonde owned by San Francisco Bay NERR at a site in the southern region of San Francisco Bay.

*Test susceptibility of oysters from sites throughout each estuary to environmental stressors representative of current and projected future conditions.*

Through collaborative interaction with end-users we decided to test oyster susceptibility to two climate change-related factors (temperature and salinity) and two other anthropogenic stressors

(sedimentation and hypoxia, both already identified by end-users as key concerns for restoration). Our experiments are testing growth and survival responses of juvenile oysters to several levels of each individual stressor. We identified treatment levels by characterizing the mean and range of stressor variation in each estuary using existing data from San Francisco Bay and Elkhorn Slough NERR monitoring programs and other previous work. For each stressor, we are using levels representing current and projected future conditions driven by climate change. We are testing each factor alone as well as in combination with others, including specifically looking at interactions between climate change-related and other anthropogenic stressors. The first of these multiple stressor experiments began in July and was designed to simulate stressors as they occur in the field (high temperature and low dissolved oxygen in the summer, low salinity events in winter, high sedimentation in winter), mimicking the timing of these events on different life stages (new recruits in summer and older juveniles in the winter). During these multiple stressor experiments, oysters will experience a realistic recovery period between the successive stressor treatments as actually occurs seasonally in the field.

*Link stressor magnitude and variance to Olympia oyster fecundity and demographics*.

Although the above laboratory work will provide us with information about the response of juvenile oysters to select environmental stressors, field conditions are likely to be significantly more complex, requiring field measurements of oyster demography to link the laboratory results to observed field responses. To better support conservation and restoration efforts, we also need to identify sites to which oysters regularly recruit and/or which support fecund individuals. We therefore have begun documenting oyster population dynamics through regular surveys of recruitment, growth, survivorship, size distribution, density, and fecundity in the field.

Recruitment is being measured on ceramic tiles mounted on frames and replaced quarterly at each site (with three additional biweekly checks in San Francisco Bay starting in June and October, representing summer and fall when fecundity and recruitment peaks have been observed in previous work). All oyster recruits on biweekly tiles are counted and saved for studies of population connectivity (see final objective below).

Oyster survival and growth rates are good indicators of habitat quality and are being measured via repeated measurements of the same set of oysters at each site over time. We are assessing growth and survival of adults settled onto tiles attached to two additional frames at each site. Blank tiles were deployed on the frames at the beginning of the settlement season in April 2012 and will be photographed quarterly throughout the project.

Fecundity is estimated from the percentage of oysters (out of up to 30 selected at random, depending on site density) that are brooding larvae during three biweekly checks starting in June and October (again representing summer and fall reproductive peaks). Any larvae present are collected, and shelled larvae are used in connectivity studies described below. Fecundity surveys are not being conducted in Elkhorn Slough due to low population numbers.

*Identify source and sink populations and the degree of connectivity between populations in San Francisco Bay.*

Sites identified as having good environmental conditions for oysters would be of relatively limited use for restoration if oysters do not naturally recruit to those sites. Thus, it is essential to understand the sources and fates of oyster larvae. Larval movement and connectivity within San Francisco Bay is being assessed by comparing shell chemistry of brooded larvae from different sites (collected in fecundity assessments) with the chemistry of recently settled recruits

collected during summer and fall (from biweekly recruitment measurements). We have completed one round of sample collection and preparation. In the next six months we will measure shell trace-element microchemistry in those samples with laser ablation inductively-coupled plasma mass spectrometry (LA ICP-MS) at University of California-Davis. Demographic models will be constructed from the connectivity, recruitment, growth, survivorship, size distribution, density, and fecundity data, enabling us to relate population changes to environmental factors measured at each site.

### D. Benefit to NERRS and NOAA

We are collecting a large amount of intertidal and subtidal environmental data that will be shared with the NERRS and various NOAA groups. Initiation of these long-term monitoring efforts marks the beginning of what we expect to be a valuable, informative, and often-used dataset filling identified gaps in the region. In particular, our continuous salinity measurements and high-frequency intertidal sampling will yield broadly useful data.

### E. Additional updates

A new CTP Coordinator (Heidi Nutters) joined the San Francisco Bay National Estuarine Research Reserve in July and is now orienting herself to the goals and scope of the project. Heidi will participate occasionally in conference calls and will work with the rest of the project team to prepare for the final training workshop to be held during summer 2014.